

Review

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Review

Perioperative Pain Relief in Pediatric Tonsillectomy: Current Strategies and Future Directions

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Abstract

Postoperative pain following pediatric tonsillectomy remains a significant clinical challenge. Inadequate management leads to delayed recovery, dehydration, and increased healthcare utilization. Multimodal analgesia, including combining systemic analgesics, local anesthetic techniques, and adjunctive medications, has emerged as the standard of care. This review highlights current perioperative pain management strategies, evaluates the role of methadone as an alternative opioid, and explores future directions in optimizing analgesia for pediatric patients undergoing tonsillectomy procedures. Local infiltration and nerve blocks provide site-specific pain relief, reducing opioid requirements and improving patient comfort. A comprehensive understanding and careful selection of analgesic regimens are crucial for enhancing outcomes in this population.

Keywords: pediatric tonsillectomy; postoperative pain; multimodal; analgesia; opioid

1. Introduction

Tonsillectomy is one of the most commonly performed surgical procedures in pediatric patients [1,2]. Postoperative pain following pediatric tonsillectomy is typically moderate to severe, often prolonged and peaking in the first 24–48 hours with a second peak around days 5–8 related to eschar sloughing. Prospective cohort data and recent reviews consistently report pain intensity in the moderate-to-severe range for many children, underscoring the need for reliably scheduled, multimodal analgesia [3–5]. Effective perioperative pain control is crucial for facilitating oral intake, reducing the risk of dehydration, and minimizing the likelihood of hospital readmissions [4]. Historically, opioids were the mainstay of analgesia; however, concerns regarding respiratory depression and other adverse effects have shifted toward multimodal approaches. These strategies integrate systemic analgesics, regional anesthetic techniques, and adjunctive agents to optimize pain relief while minimizing opioid exposure [7].

Post-tonsillectomy pain is multifactorial, arising from a combination of somatic, inflammatory, and neuropathic mechanisms. The procedure itself creates large areas of exposed pharyngeal muscle, leading to significant pain from muscle spasm and direct irritation of nerve endings [8]. The initial surgical insult triggers a robust local inflammatory response, mediated by the release of prostaglandins, bradykinin, and cytokines, which lowers the activation threshold of peripheral nociceptors and causes primary hyperalgesia at the surgical site [9].

The healing process contributes to a characteristic biphasic pain pattern. The tonsillar fossa heals via secondary intention, forming a protective fibrin eschar that increases in size over the first 3–4 postoperative days. This eschar begins to shed around day 7, exposing underlying nerve fibers and damaged muscle to mechanical stimuli from swallowing, which can exacerbate pain and delay remucosalization, often completed by the end of the second week [10]. This process explains why pain often peaks several days after surgery and may persist for up to two weeks.

Furthermore, pain can be compounded by factors related to surgical positioning. The placement of the Boyle-Davis mouth gag can cause pressure-induced ischemia and venous congestion of the tongue, leading to postoperative pain and swelling, as well as stretching of the temporomandibular joint [11]. Patients also frequently experience referred otalgia, as pain signals from the tonsillar bed (innervated by the glossopharyngeal nerve) converge on the same spinal nucleus (nucleus solitarius) as sensory fibers from the ear [12].

Inadequate pain control after pediatric tonsillectomy triggers a detrimental cycle of decreased oral intake, leading to dehydration and a heightened risk of hospital readmission. This increases the potential for postoperative hemorrhage due to pain-induced agitation and hypertension. This state of dehydration can dangerously concentrate renally cleared analgesics like non-steroidal anti-inflammatory drugs (NSAIDs) and acetaminophen, elevating the risk of acute kidney injury and hepatotoxicity. Evidence indicates that nonsteroidal anti-inflammatory drugs can precipitate acute kidney injury in children, particularly in the setting of dehydration or reduced renal perfusion, even when administered at therapeutic doses [13-17]. Similarly, acetaminophen hepatotoxicity may occur following overdose or repeated supratherapeutic dosing, especially during illness, fasting, or dehydration, due to accumulation of the reactive metabolite N-acetyl-p-benzoquinoneimine [18-22].

Furthermore, poorly managed acute pain can induce central sensitization, raising the long-term risk of chronic pain conditions, and contribute to significant psychological sequelae such as medical trauma, needle phobia, and heightened anxiety for both the child and parents [23]. Similarly, the efficacy and safety of opioids like codeine and tramadol are highly dependent on pharmacogenetics. These drugs are prodrugs that require metabolic activation by the cytochrome P450 enzyme CYP2D6. Patients with genetic polymorphisms leading to ultra-rapid metabolizer phenotypes are at risk for toxic levels of active drug and life-threatening respiratory depression, which is why they are now contraindicated in children following tonsillectomy [24]. A comprehensive understanding of these mechanisms and risks is therefore critical for selecting effective and safe analgesic regimens.

2. Multimodal Analgesia

2.1. Acetaminophen

Acetaminophen is a cornerstone of multi-modal analgesia for pediatric tonsillectomy, providing effective pain relief while directly mitigating opioid requirements. Acetaminophen primarily exerts its effects through central inhibition of cyclooxygenase (COX) enzymes and modulation of descending serotonergic pathways, thereby providing foundational analgesia [25].

This foundational role refers to acetaminophen's ability to act as the base layer of multimodal analgesia, upon which other agents can build additive or synergistic effects [26]. By providing consistent background analgesia through central cyclooxygenase inhibition and activation of descending serotonergic inhibitory pathways, acetaminophen helps reduce basal nociceptive input to the central nervous system [2]. This reduction in baseline pain sensitivity allows adjunct medications such as nonsteroidal anti-inflammatory drugs, local anesthetics, or opioids used for breakthrough pain to act more efficiently and at lower doses [27]. In pediatric tonsillectomy, this foundational effect contributes to smoother pain trajectories, fewer opioid requirements, and better tolerance of oral intake, which together form the primary goals of modern opioid sparing perioperative care [1].

In contrast, NSAIDs work predominantly in the periphery by inhibiting COX enzymes, thereby reducing the local synthesis of prostaglandins that mediate inflammation and pain [28]. This mechanistic difference is the basis for their powerful synergy, producing an analgesic effect that is greater than the sum of either agent used alone [26]. This synergy is not merely theoretical; it has been consistently demonstrated in rigorous experimental models, validated through advanced in vitro and computer-aided screening methods, and proven effective in clinical settings for various pain states, including acute postoperative pain [26,29-31]. For example, the combination of intravenous acetaminophen and ibuprofen has been shown to significantly reduce postoperative

morphine consumption and pain scores in children undergoing tonsillectomy compared with either drug alone [2,27].

Consequently, this evidence-based combination is a pivotal strategy for developing effective, opioid-sparing analgesic regimens. The efficacy of acetaminophen is maximized through scheduled, around-the-clock administration. Clinical practice guidelines strongly endorse this strategy to maintain consistent therapeutic plasma levels and provide superior pain control compared to "as-needed" dosing. [27]. The availability of an intravenous formulation is particularly valuable in the immediate postoperative period, ensuring reliable analgesia when oral intake is not feasible. Evidence demonstrates that intravenous acetaminophen effectively reduces both early and delayed pain. It significantly decreases the need for rescue morphine in the post-anesthesia care unit, enhancing early recovery safety [32].

The strategic role of acetaminophen extends beyond the hospital, forming the bedrock of successful outpatient opioid-sparing protocols. When integrated into a standardized pain management regimen, scheduled acetaminophen (often combined with ibuprofen) provides sufficient analgesia for many patients, drastically reducing or even eliminating the need for opioids at discharge. This approach directly addresses critical concerns regarding opioid-related adverse effects, such as nausea, vomiting, and respiratory depression, thereby promoting safer recovery at home. Clinical studies have proven that such protocols, with acetaminophen as a core component, are highly effective in managing pain while minimizing overall opioid exposure, facilitating a safer and more comfortable recovery for pediatric patients [2].

2.2. Non-steroidal anti-inflammatory drugs (NSAIDs) in Pediatric Tonsillectomy

As noted above, scheduled acetaminophen combined with NSAIDs such as ibuprofen provides synergistic analgesia and forms the foundation of multimodal perioperative pain control. The AAO-HNS 2019 Clinical Practice Guideline recommends combining these analgesics while minimizing opioid use, particularly in children under 12 years. (1). The PROSPECT protocol (2021) echoes this approach, recommending intraoperative dexamethasone and reserving opioids solely for rescue analgesia [33].

Historically, concerns about NSAID-associated bleeding have limited their use. A 2022 meta-regression study by Losorelli et al. examined ibuprofen at doses of 5 mg/kg and 10 mg/kg and found no statistically significant increase in post-tonsillectomy hemorrhage (PTH) [34]. Similarly, a 2013 Cochrane review of 15 trials enrolling both adult and pediatric patients found no statistically significant evidence that NSAIDs increase the risk of perioperative bleeding requiring surgical intervention, reoperation, or readmission. However, the analysis could not exclude a potential clinically substantial increase in the risk of reoperation due to wide confidence intervals [35].

In contrast, a 2024 analysis of ketorolac in 17,000 matched pediatric tonsillectomy cases revealed increased risk of both primary hemorrhage (OR 2.16, 95% CI 1.35–3.44) and secondary hemorrhage (OR 1.37, 95% CI 1.06–1.79) when administered on the day of surgery [36]. The association between ketorolac and post-tonsillectomy hemorrhage appears to be age-specific. A landmark study found that while ketorolac significantly increased the risk of hemorrhage in adults, it did not do so in children [37]. More recent studies have supported this finding of relative safety in the pediatric population [10,37].

A systematic review and meta-analysis published in *Scientific Reports* in January 2025 analyzed various pain management strategies after tonsillectomy. The study found that preoperative or intraoperative administration of NSAIDs, including ketoprofen, significantly reduced postoperative pain intensity compared to placebo or no treatment. This reduction was consistent across multiple time points, including the first 24 hours, and on days 1, 3, and 7 postoperatively [38].

Studies by Salonen and Kokki have demonstrated the efficacy of rectal ketoprofen for post-tonsillectomy analgesia in school-aged children (mean age ~7 years). Their research found that a dose of 2 mg/kg was associated with a significant reduction in opioid consumption and improved pain scores compared to placebo. However, the rectal route may present practical challenges related to

patient acceptance and adherence outside of a controlled research setting, limiting its widespread use in favor of oral or intravenous alternatives [39,40].

Selective COX-2 inhibitors have also been explored as alternatives to traditional NSAIDs in pediatric tonsillectomy. In a randomized controlled trial, Murto et al. demonstrated that celecoxib significantly reduced early postoperative pain and opioid consumption compared to placebo, with no increase in adverse events; pharmacogenetic variability was also noted, with children carrying the CYP2C9*3 allele showing enhanced analgesic effects [41]. Building on this, So et al. conducted a large retrospective cohort study of over 6,000 pediatric tonsillectomy patients and found that celecoxib use was not associated with an increased risk of post-tonsillectomy hemorrhage requiring surgery [42]. These findings suggest celecoxib may provide effective analgesia while maintaining an acceptable safety profile, though further prospective data are warranted before routine use.

Table 1. NSAIDs for Pediatric Tonsillectomy Pain Management.

Drug	Typical Pediatric Dose	Analgesic Benefit	Bleeding Risk Evidence	Notes/Guidelines
Ibuprofen	5–10 mg/kg q6–8h (max 40 mg/kg/day)	Adequate analgesia reduces opioid rescue use	No significant increase in PTH (Losorelli 2022; Military Medicine 2024) Mixed evidence; slightly higher	AAO-HNS 2019: Strongly recommended
Ketorolac	0.5 mg/kg IV q6h (max 30 mg/dose, 120 mg/day)	Opioid-sparing in some trials	bleeding signal in adults; pediatric data are less clear	Use cautiously; not first-line
Diclofenac	1 mg/kg PO/PR q8h (max 75 mg/day)	Some pediatric data for analgesic benefit	Limited tonsillectomy data; no clear bleeding signal	More common in Europe; less used in the US
Ketoprofen	0.5–1 mg/kg IV at induction, then 3 mg/kg over 24h; or 3–5 mg/kg/day PO divided q6–8h	Adequate analgesia reduces opioid requirement	Limited pediatric tonsillectomy data; generally, no increased bleeding in controlled studies	Use with caution; monitor for Gastrointestinal or renal side effects.
Celecoxib	3 mg/kg PO q12 h (max 400 mg/day)	Reduces early postoperative pain and opioid use with a favorable safety profile	No increased risk of post-tonsillectomy hemorrhage requiring surgery	Effective COX-2–selective option with favorable safety profile; further prospective studies recommended before routine use

2.3. Role of Opioids

The role of opioids in pediatric tonsillectomy analgesia has been dramatically redefined, shifting from a first-line treatment to a limited, rescue-only therapy due to significant safety concerns. This paradigm shift is driven by evidence that routine opioid use, particularly codeine and hydrocodone, poses a substantial risk of fatal respiratory depression in children, leading to FDA black box warnings against their use in this population. [1,43]. Consequently, multi-modal, opioid-sparing protocols built on scheduled acetaminophen and NSAIDs like ibuprofen are now the standard of care, as they provide adequate analgesia without increasing bleeding risk and have been proven to significantly reduce or even eliminate the need for opioids in most patients. [2,44]. When severe breakthrough pain occurs, low-dose, weight-based oxycodone is often preferred over other opioids for rescue therapy. Still, its use must be carefully weighed against the risk of adverse effects, which include nausea, vomiting, and respiratory compromise [24,45]. National initiatives and institutional quality improvement projects have successfully demonstrated that standardizing pain management protocols to minimize opioid prescribing is both safe and effective, drastically reducing opioid

exposure while maintaining satisfactory pain control. [44,46].

Methadone is a long-acting μ -opioid receptor agonist with additional N-methyl-D-aspartate (NMDA) receptor antagonism, producing prolonged postoperative analgesia through dual mechanisms that reduce both nociceptive and central sensitization pathways. Randomized controlled trials in pediatric tonsillectomy have evaluated intravenous methadone at doses of 0.10 to 0.15 mg per kg, demonstrating effective opioid sparing and improved early postoperative comfort compared with short acting opioid regimens[47]. However, methadone should not be considered a first line outpatient opioid in children because of its long and variable half-life, risk of accumulation, and potential for delayed respiratory depression. In addition, methadone can prolong the QT interval, predisposing susceptible patients to torsades de pointes; therefore, careful patient selection, review of baseline electrocardiogram, and monitoring for QT prolongation are recommended [46]. When used appropriately, methadone is best regarded as an intraoperative adjunct for sustained analgesia within an opioid sparing multimodal regimen, rather than a routine postoperative analgesic [46,47].

2.4. Pre-Emptive Analgesia

Pre-emptive analgesia refers to administering analgesics before the surgical stimulus to attenuate central sensitization, decreasing postoperative pain, and reducing opioid requirements. In pediatric tonsillectomy, this approach complements multimodal analgesia strategies and may optimize recovery.

The choice of primary anesthetic agent itself can be considered a foundational pre-emptive strategy. Although prior studies have hypothesized that propofol-based anesthesia might attenuate postoperative hyperalgesia compared with volatile agents, the current evidence indicates comparable clinical efficacy between propofol and sevoflurane in terms of pain control and recovery quality [48]. Randomized controlled trials support the use of intravenous ibuprofen (10 mg/kg administered ~15 minutes before incision) to reduce postoperative opioid rescue requirements without increasing the risk of nausea, vomiting, or postoperative hemorrhage. However, the practical implementation of this specific protocol may be limited by operating room logistics, the higher cost of intravenous formulation, and the widespread efficacy of pre-operatively administered oral ibuprofen [49]. Similarly, the structured use of acetaminophen in combination with NSAIDs aligns with evidence-based multimodal regimens endorsed by the AAO-HNS Clinical Practice Guideline (2019) and the PROSPECT recommendations (2021)[33].

Dexamethasone, a potent long-acting corticosteroid, is a cornerstone of multimodal analgesia and antiemetic prophylaxis in pediatric tonsillectomy. Its mechanism of action is primarily rooted in its potent anti-inflammatory and immunosuppressive effects. It inhibits phospholipase A2, preventing the release of arachidonic acid from cell membranes and thereby suppressing the entire cascade of inflammatory mediators, including prostaglandins and leukotrienes. This reduction in local inflammation and edema at the surgical site directly correlates with reduced pain scores and facilitates earlier oral intake. Furthermore, its antiemetic effect is mediated by central inhibition of serotonin release in the chemoreceptor trigger zone (CTZ)[50-52].

When administered intraoperatively (0.5 mg/kg, maximum 8-20 mg), dexamethasone provides consistent benefits, including reduced pain scores, a delayed time to the first request for rescue analgesia, earlier resumption of oral intake, and a significant reduction in postoperative nausea and vomiting (PONV)[51,52]. A 2025 prospective, randomized controlled non-inferiority trial by Brooks Peterson et al. demonstrated that oral dexamethasone (0.5 mg/kg) is not inferior to the intravenous formulation in reducing postoperative nausea and vomiting and improving pain outcomes in children undergoing tonsillectomy, providing a compelling and practical alternative for perioperative care [53].

Recent evidence suggests that a short oral course of corticosteroids after tonsillectomy may provide additional analgesic benefit once patients are discharged. Shayan et al. demonstrated that oral prednisolone significantly reduced pain scores and analgesic requirements following tonsillectomy with sutures compared with standard care. This finding supports consideration of a limited, closely

monitored home taper of oral corticosteroids, such as prednisolone, as part of multimodal pain management when clinically appropriate [54].

Adjunctive agents such as gabapentinoids have been explored for their potential to modulate neuropathic and central sensitization components of post-tonsillectomy pain [55]. Their proposed mechanism of action involves binding to the $\alpha 2\delta$ -1 subunit of presynaptic voltage-gated calcium channels in the central nervous system. This binding inhibits the release of excitatory neurotransmitters (e.g., glutamate, substance P) involved in pain signaling, thereby dampening hyperexcitability and potentially preventing the wind-up phenomenon.

Despite this rational pharmacological basis, pediatric evidence for their efficacy specifically in tonsillectomy remains limited. A small pilot trial of gabapentin (10 mg/kg orally) suggested reduced analgesic consumption post-discharge but no significant improvement in pain scores, highlighting the need for larger, definitive studies before routine adoption can be recommended [56].

3. Role of Honey in Postoperative Pain Management

Honey has traditionally been considered a natural remedy for alleviating postoperative pain due to its soothing properties and potential antimicrobial effects. Its use in pediatric tonsillectomy has been explored as a non-pharmacologic intervention to reduce pain, improve swallowing, and potentially decrease the need for analgesics.

However, a recent large, multicenter, double-blind randomized controlled trial (the BEE PAIN FREE Trial) provides robust evidence that honey is not effective for this purpose. The study found that administering honey after pediatric tonsillectomy did not significantly reduce postoperative pain scores or opioid consumption compared to a placebo syrup. This high-quality evidence indicates that honey does not provide clinically meaningful analgesic benefits in this population [57].

In a randomized, double-blind, placebo-controlled study conducted by Boroumand et al., a statistically significant difference was observed between the acetaminophen and acetaminophen-plus-honey groups in terms of both Visual Analogue Scale (VAS) scores and the number of painkillers taken during the first three postoperative days. Analgesic consumption also differed significantly across each five-day postoperative interval. However, no significant difference was found between the groups regarding the number of night time awakenings [58].

Honey has demonstrated a broad spectrum of therapeutic properties that make it a valuable agent in wound management. It exhibits potent antimicrobial activity, modulates inflammatory responses, and stimulates immune function. Additionally, honey facilitates autolytic debridement, promotes granulation tissue formation, and accelerates epithelialization, thereby enhancing overall wound healing. Its ability to support the healing of chronic or non-healing wounds has also been well documented. Owing to its combined antimicrobial, antioxidant, and anti-inflammatory properties, honey has been successfully employed in the treatment of various wound types, including burns, ulcers, and other skin lesions [59]. A 2017 systematic review and meta-analysis by Lal et al. (eight RCTs) suggested that honey reduced postoperative pain, analgesic use, and nocturnal awakenings after tonsillectomy. However, the overall evidence quality was rated low to very low due to methodological limitations [60].

In conclusion, although honey is safe and widely accepted as a complementary intervention, current evidence does not support its routine use as an effective analgesic for pediatric tonsillectomy. Clinicians should prioritize evidence-based pharmacologic strategies for postoperative pain management, while honey may be considered only as an adjunct with limited analgesic expectations.

4. Home Pain Management & Complementary Therapies

A critical safety principle is the absolute contraindication of codeine. This is due to its potential for unpredictable, life-threatening respiratory depression, a risk mechanistically driven by its metabolism via the cytochrome P450 enzyme CYP2D6. Children with ultrarapid metabolizer phenotypes convert codeine to morphine too efficiently, resulting in toxic blood levels that severely

depress the brainstem's respiratory drive [2,61,62] Consequently, the SAMBA statement strongly supports scheduled acetaminophen and ibuprofen while discouraging opioids like codeine or tramadol, particularly in children with obstructive sleep apnea (OSA), who are at an elevated baseline risk [63].

Structured discharge protocols should include:

- Written dosing charts for scheduled analgesics
- Hydration and diet guidance (soft foods, frequent fluid intake)[1].
- Caregivers should be educated on referred otalgia (ear pain), a common occurrence that does not indicate an ear infection. This pain arises because the tonsillar fossa and ear canal share innervation from the glossopharyngeal nerve (cranial nerve IX). The brain misinterprets pain signals from the healing surgical site as originating from the ear. Preparing parents for this expected symptom, which often peaks around days 3-7, reduces anxiety and prevents unnecessary concerns for infection [2,12].

Caregiver counseling is crucial for safe postoperative care, including:

- Medication education: alternating acetaminophen and NSAIDs safely, maximum daily doses, recognizing inadequate pain control [1,33].
- Hydration and nutrition: ensuring adequate fluid intake and soft foods to prevent dehydration [1].
- Monitoring for complications: signs of secondary hemorrhage (days 5–10), dehydration, or respiratory distress [1,36].
- Non-pharmacologic strategies: distraction, music therapy, relaxation, comfort measures [2].
- Emergency planning: clear guidance for contacting healthcare providers [1].

Structured caregiver counseling improves adherence to pain management, reduces complications, and enhances recovery outcomes. There is a plethora of non-medication approaches that can be used to alleviate tonsillectomy pain in children. Ice cream is commonly depicted in popular media as the standard home remedy for tonsillectomy pain. Ice cream and other cold foods such as popsicles or ice chips provide a local cooling effect that can help to reduce pain by decreasing inflammation in the oropharynx and numbing the surgical site [64]. The mechanism of this is most likely related to vasoconstriction in the oropharynx and numbing of local nerve endings [65,66]. In a randomized control trial setting, ice-lollies have been shown to significantly reduce pain scores in the immediate post-operative period up to one hour compared to no intervention, highlighting the importance of ice cream as an effective and accessible supplement to short-term pain relief [67]. The American Academy of Otolaryngology explicitly recommends cold application, which includes the consumption of ice cream, as a supplement in a larger multimodal analgesia plan towards alleviating tonsillectomy pain in children [1].

Table 2. Structured Home Pain Management and Supportive Measures.

Component	Recommended Practice	Supporting Evidence/Guidelines
Scheduled dosing	Alternate acetaminophen and ibuprofen for the first 48 h	AAO-HNS 2019 (Mitchell et al., 2019); PROSPECT 2021 (PROSPECT Working Group, 2021)
Rescue analgesia	Short opioid (e.g., oxycodone) only if uncontrolled pain; avoid codeine/tramadol	FDA safety warnings; AAO-HNS 2019 (Mitchell et al., 2019)
Hydration & diet	Encourage frequent fluids; soft diet	Reduces dehydration risk, improves recovery (Mitchell et al., 2019)
Caregiver education	Written instructions with dosing charts, warning signs	Improves adherence and outcomes (Jensen, 2021)
Non-pharmacologic adjuncts	Distraction, music therapy, relaxation techniques	Low-risk, caregiver-implementable (Jensen, 2021)
Follow-up/safety	24-h access to provider; monitor for secondary hemorrhage (days 5–10)	Guideline consensus (Mitchell et al., 2019; Shaikh et al., 2024)

5. Local Infiltration and Nerve Blocks

Several local anesthetic techniques are effective components of a multimodal strategy for reducing postoperative pain and analgesic requirements in children following tonsillectomy. Bupivacaine instillation has been shown to provide superior postoperative analgesia and facilitate earlier recovery [68]. Furthermore, Ju et al. reported that combining dexamethasone with 0.2% ropivacaine for local infiltration significantly reduced postoperative pain (4–24 h), analgesic use, PONV incidence, and time to discharge, while improving oral intake, compared to ropivacaine alone [69]. This supports earlier findings that pre-incisional infiltration of local anesthetic can significantly reduce post-tonsillectomy pain in pediatric patients [70].

The glossopharyngeal nerve block has also emerged as a valuable technique for enhancing postoperative pain control. A randomized controlled trial demonstrated that its application significantly delays the time to the first request for rescue analgesia and reduces total postoperative opioid consumption [71]. Collectively, when integrated with systemic analgesics, these regional techniques form a comprehensive multimodal approach that enhances analgesic efficacy and reduces opioid exposure [33].

A recent randomized trial by Lin et al. (2024) demonstrated that suprazygomatic maxillary nerve blocks (SZMB) with ropivacaine significantly reduced total opioid consumption and lowered pain scores on PACU arrival in children undergoing adenotonsillectomy. The intervention group also experienced a prolonged time to first request for rescue analgesia compared to the sham block control group. The authors concluded that SZMB is a safe and effective technique for enhancing multimodal, opioid-sparing pain management in this patient population [72].

A 2024 randomized trial by Atef et al. directly compared ultrasound-guided versus landmark-based techniques for this block in pediatric tonsillectomy. The study demonstrated that ultrasound guidance provided superior postoperative analgesia, resulting in significantly lower pain scores and reduced rescue analgesic requirements in the first 24 hours compared to the blind technique, without an increase in complications [73].

6. Surgical Techniques for Tonsillectomy and Adenoidectomy and Their Impact on Postoperative Pain

6.1. Tonsillectomy Techniques

6.1.1. Extracapsular (Total/Traditional) Tonsillectomy

- Description: Complete removal of the tonsil along with the capsule, fully exposing the pharyngeal muscles. Hemostasis is achieved via ligation, cautery, or electrocautery.
- Pain Implications: Exposure of pharyngeal muscles and nerve endings leads to higher postoperative pain, increased analgesic requirements, and delayed return to normal diet and activities.
- Pain Management Considerations: Requires scheduled NSAIDs and acetaminophen; opioids may be used for breakthrough pain [74,75].

6.1.2. Intracapsular (Partial/Subtotal) Tonsillectomy

- Description: Tonsillar tissue is removed while leaving a thin rim of tonsillar capsule intact, minimizing exposure of pharyngeal muscles and sensory nerves. Hemostasis is typically achieved using coblation, microdebrider, or low-thermal electrosurgery.
- Pain Implications: Significantly lower postoperative pain reduced analgesic use, and faster resumption of oral intake and normal activities in children compared to extracapsular techniques.
- Pain Management Considerations: NSAIDs and acetaminophen are generally sufficient; opioids are rarely required [76,77].

6.1.3. Electrocautery/Bovie Tonsillectomy

- Description: Uses high-frequency electric current for cutting and coagulation. Offers excellent intraoperative hemostasis but may cause thermal tissue injury.
- Pain Implications: Associated with increased thermal damage and higher postoperative pain compared to low-temperature techniques such as coblation.
- Pain Management Considerations: Multimodal analgesia (acetaminophen + NSAIDs ± opioids) is commonly required [75].

6.1.4. Coblation (Cold Ablation) Tonsillectomy

- Description: Low-temperature radiofrequency energy removes tonsillar tissue while minimizing damage to surrounding muscle and nerves. Hemostasis is achieved with low thermal coagulation.
- Pain Implications: Children undergoing coblation tonsillectomy discontinue prescription opioids one day earlier than those undergoing electrocautery and use approximately half as many opioid doses. Parents report the postoperative experience as “better than expected.” [74,77].
- Pain Management Considerations: NSAIDs and acetaminophen are generally sufficient; opioids rarely required.

6.1.5. Harmonic Scalpel Tonsillectomy

- Description: Uses ultrasonic energy for dissection and coagulation, reducing thermal spread.
- Pain Implications: Moderate postoperative pain; less thermal injury than electrocautery.
- Pain Management Considerations: NSAIDs and acetaminophen are usually adequate [75].

6.1.6. Microdebrider Tonsillectomy

- Description: Partial removal of tonsillar tissue, often in an intracapsular approach.
- Pain Implications: Associated with reduced pain and faster recovery compared to traditional techniques.
- Pain Management Considerations: NSAIDs and acetaminophen suffice in most cases [77].

6.2. Adenoidectomy Techniques

6.2.1. Cold Curettage Adenoidectomy

- Description: Adenoid tissue is removed with a curette or suction curette.
- Pain Implications: Mild postoperative pain; generally well-tolerated.
- Pain Management Considerations: NSAIDs or acetaminophen are sufficient [75].

6.2.2. Electrocautery/Radiofrequency Adenoidectomy

- Description: Adenoid tissue is ablated with electrocautery or low-temperature radiofrequency energy.
- Pain Implications: Slightly more pain than cold curettage, but still mild.
- Pain Management Considerations: Scheduled acetaminophen or NSAIDs; pre-emptive analgesia may be beneficial [74].

Table 3. Surgical Technique and its effect on Pain and Analgesic requirement.

Technique	Description	Pain Level	Analgesic Requirement
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Extracapsular (Total) Tonsillectomy	Complete removal of tonsil + capsule; pharyngeal muscles exposed	High	Scheduled NSAIDs + acetaminophen; opioids may be needed
Intracapsular (Partial/Subtotal) Tonsillectomy	Leaves a thin rim of tonsillar tissue/capsule intact	Low	NSAIDs + acetaminophen; opioids rarely required
Electrocautery/Bovie	High-frequency electric current for cutting/coagulation	High	Multimodal analgesia; opioids are more likely
Coblation (Cold Ablation)	Low-temp radiofrequency energy; minimal thermal injury	Low	NSAIDs + acetaminophen; opioids rarely needed
Harmonic Scalpel	Ultrasonic energy for cutting/coagulation	Moderate	NSAIDs + acetaminophen
Microdebrider (Intracapsular)	Partial tissue removal using a microdebrider	Low	NSAIDs + acetaminophen
Cold Curettage Adenoidectomy	Adenoid tissue was removed with a curette	Mild	NSAIDs or acetaminophen
Electrocautery/Radiofrequency Adenoidectomy	Adenoid ablation with electrocautery/RF	Mild-Moderate	NSAIDs or acetaminophen; pre-emptive analgesia is beneficial

Key Points

- Intracapsular tonsillectomy offers the most significant reduction in postoperative pain and opioid use in children.
- Coblation provides significant benefits over traditional electrosurgery in terms of opioid use and patient/parent satisfaction.
- Choice of surgical technique and hemostasis method directly affects postoperative pain, analgesic requirements, and recovery speed.

7. Future Directions

The evolution of pain management strategies for pediatric tonsillectomy is poised to focus on refining multimodal, opioid-sparing protocols through technological integration, precision medicine, and the validation of novel techniques. The established efficacy of Enhanced Recovery After Surgery (ERAS) principles, which combine scheduled acetaminophen, NSAIDs, and regional anesthesia, provides a robust foundation for this evolution. [2,6]. Future efforts will likely concentrate on optimizing each component of this approach.

A primary direction involves the standardization and widespread adoption of advanced regional techniques, particularly with technological assistance to improve efficacy and safety. The recent demonstration that ultrasound-guided glossopharyngeal nerve blocks provide superior and more reliable analgesia than landmark-based techniques underscores a significant opportunity [73]. Future research should focus on developing standardized protocols for ultrasound-guided blocks, training modules for surgeons and anesthesiologists, and investigating the synergistic effects of combining different nerve blocks (e.g., maxillary and glossopharyngeal) for more comprehensive pain control.

The future of pain management in pediatric tonsillectomy is poised to move beyond standardized protocols toward a paradigm of personalized, opioid-free precision medicine, leveraging advancements in pharmacogenomics and immersive technology. The established foundation of multimodal analgesia, which effectively combines acetaminophen, NSAIDs, and regional techniques, will be enhanced by tailoring interventions to the individual patient's genetic profile and psychological state.

A critical direction involves the clinical implementation of preemptive pharmacogenetic testing to guide analgesic selection and dosing. As demonstrated by the clinical application of CYP2D6 genotyping to avoid codeine in poor and ultrarapid metabolizers, there is a clear precedent for using genetic data to prevent adverse drug reactions and improve efficacy [61,62]. Future protocols will likely expand this concept to create comprehensive genetic profiles that inform the use

of other opioids and non-opioid adjuvants, ensuring the right drug at the correct dose for the right patient and fundamentally eliminating genetically mediated toxicity.

Concurrently, the integration of non-pharmacologic, digital therapeutics will become a standard component of perioperative care. Evidence from meta-analyses confirms that immersive virtual reality (VR) is an effective tool for reducing procedural pain and anxiety in children by engaging multiple senses and demanding cognitive attention, thus acting as a powerful distractor [78]. Future research should focus on implementing VR not just for needle procedures but also for managing postoperative pain at home, providing a potent, zero-risk analgesic adjunct that empowers children and reduces reliance on medications.

Laser tonsillectomy is a promising surgical approach to reduce postoperative pain and hasten recovery. Several randomized and comparative studies report lower early postoperative pain scores, reduced intraoperative blood loss, and faster return to normal diet with laser techniques compared with conventional dissection or cautery in children and adults. Systematic reviews and comparative analyses suggest laser and other low-thermal techniques may offer analgesic advantages, though results vary by laser type and study design. Larger, contemporary randomized trials are needed to confirm these benefits and to evaluate hemorrhage risk and long-term outcomes before routine adoption [79-83].

Quality improvement and implementation science are also transforming perioperative care. A 2025 study described the development and implementation of a perioperative pediatric tonsillectomy pain management toolkit designed to standardize multimodal analgesia, enhance recovery pathways, and improve caregiver education across institutions. Such toolkits may facilitate consistent opioid-sparing practice, reduce variability in pain control, and promote adherence to evidence-based protocols in pediatric tonsillectomy [84].

Ultimately, the goal is a fully integrated and personalized recovery pathway. The future standard of care will likely involve a pre-operative genetic workup to create a tailored analgesic plan, combined with prescribed digital VR therapy for home use. This approach promises to maximize safety and efficacy, minimize opioid exposure to zero for most patients, and transform the tonsillectomy recovery experience for children and their families.

Supplementary Materials: Table 1, 2 and 3.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization H.M, M.V and S.S; Methodology H.M and M.V.; validation M.V, D.S and S.S ; formal analysis, H.M, M.V and D.S; investigation, H.M; resources, H.M, M.V; data curation, H.M; writing—original draft preparation, H.M, A.C and S.Y; writing—review and editing, M.V, D.S ; visualization, M.V, S.S and D.S; supervision, S.S ; project administration, M.V and S.S ; All authors have read and agreed to the published version of the manuscript."

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Abbreviations

The following abbreviations are used in this manuscript:

NSAID	Non steroidal Anti-Inflammatory Drug
COX	Cyclooxygenase
PTH	Post Tonsillectomy Hemorrhage
PO	Per Oral
PR	Per Rectal
IV	Intra Venous
NMDA	N-methyl-D-aspartate
CTZ	Chemoreceptor Trigger Zone
PONV	Post Operative Nausea and Vomiting
VAS	Visual Analogue Scale
RCT	Randomized Control Trial
OSA	Obstructive Sleep Apnea
SZMB	Supra Zygomatic Maxillary nerve Block
PACU	Post- Anesthesia Care Unit
ERAS	Enhanced Recovery After Surgery
VR	Virtual Reality

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